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RESIDENTIAL BOTTOM-UP LOAD MODELLING WITH PRICE ELASTICITY

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Overview

Residential electricity demand accounts for around 29% in Europe (Eurostat European Commission, 2013). Nevertheless, detailed information on specific load profiles of individual households is scarce, mainly due to two reasons. First, in the past it was not necessary to fully understand the consumption behavior of households as standard load profiles where sufficiently accurate to predict residential demand (Dickert and Schegner, 2011). Second, collecting detailed information requires more sophisticated technology than Ferraris meters that are standard in many European households. Installing smart meters, which allows collecting data in a higher timely resolution, is costly and consequently not yet done on a large scale in most European countries, especially not in Germany (Flath *et al.*, 2012; Jagstaidt *et al.*, 2011).

As a consequence of the German “Energiewende” (energy transition mainly based on renewable energy sources), the electricity generation becomes more distributed and highly volatile at the same time. Many households installed photovoltaic systems (PV) on their roofs and the incentive for self-consumption recently increased due to diminishing feed-in tariffs. Also other trends, such as using heat pumps or mirco-CHP systems (combined heat and power) for residential heat generation, lead to a change in residential electricity demand. These changes in residential demand cannot be reflected by standard load profiles and require more individual approaches (Dickert and Schegner, 2012). As, in general, metered data is not available, many researchers developed synthetic bottom-up load models (for an overview on existing models see Grandjean *et al.*, 2012 and Swan and Ugursal, 2009). The main difference of the model presented in this paper compared to others developed so far, is the consideration of residential price elasticity of demand, measured in a field test, allowing the impact of electricity tariffs with dynamic prices to be simulated.

Method

A probabilistic residential bottom-up load model is developed based on the equipment of households with specific electric appliances and additional residential heat or electricity generation technologies, e.g., PV or heat pumps, their time of use, frequency of use and their specific electricity load profiles. The data used in the model stems both from official sources, for instance time of use studies and the equipment of households with electric appliances of the German Federal Statistical Office (Statistisches Bundesamt (Destatis), 2004, 2013), and measured data in sample households, e.g., specific load profiles of selected electric appliances.

In order to enable the model to simulate the impact of electricity tariffs with dynamic capacity (€/kW) or energy charges (€/kWh), the price elasticity of demand of households is implemented. The residential price elasticity is derived from a field test within the *MeRegio* project where the load profiles of up to 1,100 households were metered while using electricity tariffs with dynamic energy charges (Hillemacher *et al.*, 2013). Including measured residential price elasticity data in a bottom-up load model is the major advantage of this model over already existing bottom-up models. The simulated results of the model are validated against measured load profiles of sample households.

Results

The developed bottom-up load model can be used in various analyses in the context of the German “Energiewende” as well as abroad if adapted to country specific data, e.g., the equipment of households with electric appliances. The simulated load profiles can be used to evaluate the impact of an increased penetration of PV or other technologies in low voltage grids, for instance to analyze the influence of new tariffs or market mechanisms on residential electricity demand or the impact of new technologies on households’ total electricity demand and peak load.

Within this paper, results are presented with regard to residential load profiles. Based on the price elasticity, measured in a field test, it can be shown with the model that electricity tariffs with dynamic energy charges can be used for load management purposes and that the equipment of households is a key driver for the magnitude of load management opportunities. Electric appliances differ in their ability for load management and consequently households with a higher number of suitable appliances are more likely to shift loads than others (ETG-Task Force Demand Side Management, 2012). Additionally, the model underlines the need for more individual load profiles when analyzing small residential systems and may be used to provide valuable input data for analyzing the impact of new tariff structures on the low voltage grid stability. The available standard load profiles do not reflect individual households properly, especially when new technologies for heat and electricity generation are taken into account.

Conclusions

Bottom-up load modelling has proven to be an adequate means to simulate residential load profiles for small systems (Swan and Ugursal, 2009). In systems with less than 150 households, the existing standard load profiles cannot be used anymore and other solutions like bottom-up models are required (Esslinger and Witzmann, 2012). In the course of the "Energiewende" with an increasing share of distributed and volatile electricity generation, the analysis of small, distributed systems becomes more important. As hardly any measured data exists on household level, the presented model allows creating synthetic load profiles to be used in various analyses with regard to the impact of the "Energiewende". The main advantage of this model over other existing bottom-up load models is the integration of residential price elasticity, based on primary data from a field test, influencing households' electricity demand in case of tariffs with dynamic energy charges.

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